Work in Progress: MiceNet: Monitoring Behaviour of Laboratory Mice with Sensor Networks

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Abstract—**Medical research uses laboratory mice for experimental studies. Currently, symptoms are manually observed and recorded, resulting in noisy data – requiring many animals to obtain statistically significant results. We propose the use of a camera sensor network attached to mice cages as a low-cost solution for continuously monitoring mouse behavior and providing remote access to the data for scientists. The benefits of this approach are discussed along with challenges encountered in the initial phases of deployment. The proposed hardware and software architecture is described and early experimentation results are presented.**

I. PROBLEM CONTEXT

Experimentation with mice is an important tool for medical research. Our medical partner exposes large populations of mice with different genotypes to diseases, and the symptoms shown by the mice are studied with the goal of finding a correlation between the presence of certain genes and disease symptoms. For a typical experiment, few hundreds of mice are kept in many tens of cages in an animal facility under controlled environmental conditions. Observation of the symptoms today is performed manually, with caretakers visiting the mice few times a day and recording the symptoms (such as degree of mobility) according to their personal judgement. Later, a statistical analysis of the collected data is performed. This manual approach has several drawbacks. Firstly, the diagnosis is highly subjective and does not only vary among different observers, but also over time for a single observer, e.g., due to fatigue. Secondly, the observation is sporadic, activities between observations are not recorded. This results in substantial noise in the observation data. In order to obtain statistically significant results, the noise has to be eliminated by averaging over a large number of mice.

By introducing an automatic system to perform a more objective and continuous observation, the amount of noise and therefore also the number of required animals could be greatly reduced. As discussed in the subsequent section, commercial systems have recently been introduced for this purpose. However, they are not only expensive, but they require non-standard cages so that most of existing infrastructure has to be replaced. Our aim is therefore to design a low-cost solution based on sensor networks that can be attached to standard cages. In this paper we describe our ongoing work towards this goal.

II. RELATED WORK

Standalone structures, such as the Oxymax CLAMS system [1], offer great complexity and the ability to measure a vast range of parameters. The system uses specific cages and modules and a suite of dedicated specialized hardware and software. An alternative is LABORAS [2] which represents a system for automatic registration of behaviour in mice and rats. By means of pressure sensors, it records and analyzes the pattern generated by mice or rats during common activities.

Animal monitoring as an application domain for wireless sensor networks is well referenced in the literature [3], [4], [5]. Starting from large animal such as zebras, researchers have gone all the way down to small birds in deploying wireless sensor networks that either track a certain animal or group or perform a non-invasive monitoring of its habitat. The application that resembles most our scenario is presented in [4] where using a custom leather pouch, sensor nodes are attached to Norwegian rats.

III. APPROACH

Our working environment is an animal facility holding many tens of cages with four to five mice each. The cages have to be cleaned once a week, this is typically performed by placing the mice into a fresh cage, thus actually replacing the cage. Our test subjects are albino laboratory mice from the BALB/c strain [8]. The mice look almost identical for the human eye. Their normal adult weight is 20 to 25g, being 8-12 times smaller as a rat as considered in related work [4]. This represents a significant challenge, as the maximum weight of equipment that can be attached to a mouse is 5% of their body weight (<1g).

Based on these constraints, we decided for an approach where a sensor node equipped with a miniature camera is attached to the cage to observe the mice. Only visual markers have to be attached to the mice to be able to distinguish them, thus staying within the weight limit. Being battery-powered, the sensor nodes are wireless and can be easily attached to the cage, such that cages can be moved and replaced. The nodes attached to different cages form a wireless network, routing data from sensor nodes to a mains-powered base station that connects to the Internet, thus providing online and remote access to the collected data.

Fundamental challenges are the constrained energy, computing, storage, and communication resources of sensor nodes. This is especially true when working with image sensors that produce relatively large amounts of data. Our approach to address this challenge is two-fold. Firstly, instead of recording a continuous video stream, we use a passive infrared motion detection sensor. Only when movement is detected, the camera is switched on to record an image. Secondly, we intend to perform image processing or preprocessing (e.g., cropping the image to user-defined regions of interest) directly on the sensor nodes instead of transmitting complete images to the base station as many nodes have to share the limited network bandwidth.

This approach is low-cost as sensor nodes are relatively cheap and existing cages can be used, it provides continuous observation in an objective way, thus reducing noise and the number of mice needed. It can also reduce the amoung of labor, as scientists can observe animals remotely without entering to the animal facility (which often requires non-trivial desinfection procedures).

IV. CHALLENGES

This section discusses the challenges which need to be overcome for a successful system implementation of mouse monitoring using imaging sensor networks. It includes the problem description along with proposed approaches in most cases.

Mouse identification Due to space constraints and social behaviour, mice are kept together in cages in groups of 4-5 mice/cage. Their common genetic pattern makes distinguishing them based on individual traits difficult for the human eye as well as for machine vision. For identification, we have used color marking based on a permanent paint-based marker and food coloring. As part of their usual grooming activity the mice consistently clean the marked areas and the marker approach lasted for longer. From our preliminary results, a properly applied marking can make the identification persist for 1-2 weeks.

Cage and camera coverage issues Mice are kept in a standard laboratory cage (Fig. 1) made of hard transparent plastic. It is covered by a metallic grille which also acts as food and water holder. Approximate cage size is 27x15x42cm (WxHxL), with a ground surface of ca. 825 cm^2. The irregular shape makes observing mouse behaviour challenging in a single-camera scenario. Due to space constraints the camera sensor node needs to be attached to the cage, either to the top grille for a top-down view or in a corner for a wider field of view. We are evaluating replacing the lens with a wider angle lens. This would show considerably increase covered area; the image distortion can be compensated by software.

Climbing When in their active period, mice move not only on the ground, but also climb and hang onto and move about upside-down on the top grille. This movement makes observing them tricky as the camera has a fixed position. Experimenting with a raised top grille showed that mice spend less time climbing and hanging, due to the higher effort it takes to get there but this also restricts their access to food which can have an impact on their behaviour and the test results.

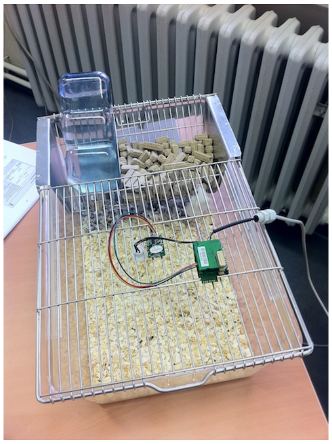


Fig. 1. Actual cage with overhead camera/sensor node placement

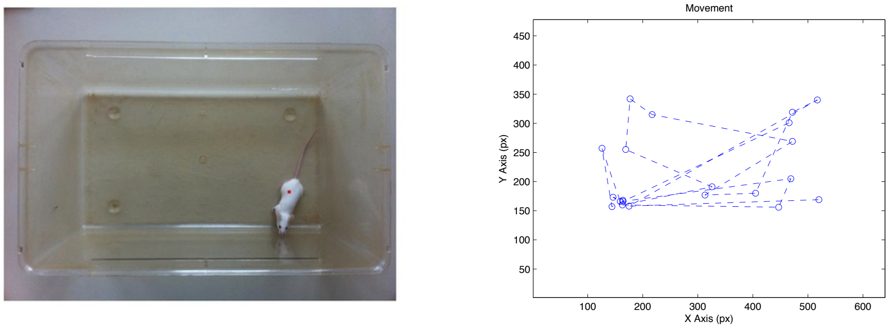
Picture quality The camera module of the sensor node offers a level of detail that is sufficient for image processing, ligthing condition changes such as direct light or shades have a significant impact on the final image which requires a robust processing algorithm to cope with those artifacts. Another challenge is that the pattern of the conventional wood shaving substrate is constantly changed by mouse movement or reflections.

Animal circadian rhythm Mice spend most of the day sleeping and sporadically engaging in activities such as eating/drinking, climbing, grooming. An activity peak is observed immediately after the beginning of darkness and a lower one just before dawn. They spend the night alternating rest with activity. While our tests were made mostly during the day, night-time monitoring is an important feature which cannot be ignored. The proposed solution involves using an IR-illuminator and a camera suitable for night vision.

V. SYSTEM DESCRIPTION AND EXPERIMENTATION

The hardware architecture of the system is composed of Coalesenses iSense Core2 Modules [6] with attached security module. It is build around a Jennic 5148 microcontroller (4-32 MHz, 128 kB ROM, 128kB RAM, integrated IEEE 802.15.4 radio). The security module includes a PIR sensor, 3-axis accelerometer and a camera board [7]. It includes an OV7640 sensor and can take still frames at up to 640x480 resolution with the lens offering a 42 horizontal and 16.5 vertical field of view. Development for the iSense platform is done in C++ with the supplied toolchain.

We performed initial experiments to assess the feasibility of identifying and tracking mice, as mice mobility is one of the most important properties for our medical partner. We first focused on tracking a single mouse without wood shaving substrate and without the top grille. A single mouse is placed



(a) (b)

Fig. 2. Early Experimentation (a) Test setup and identification with single mouse (b) Movement pattern resulting from position analysis

in the test cage and pictures are taken from a top-down view which cover the whole area of the cage (see Figure 2(a)).

In the experiments, the recorded images are compressed, timestamped and sent to the base station for further image processing. We have devised a MATLAB script which implements image processing on our data. The script processes the images in the folder and outputs the x and y coordinates of the mouse. The input picture is first converted to greyscale and then background substraction is performed with a reference background image. The next step includes small object removal and morphological detection. The dorsal side of the mouse is modelled as a disk with the diameter above a certain threshold. After identifying the object and increasing its intensity, we compute the centroid and place a red marker on the original color picture. The coordinates of the centroid are stored. To handle multiple mice with color markers, this processing chain would be repeated for every mouse by first filtering the image for the marker color.

For result validation, we have taken a set of 25 frames over the course of 15 minutes. This data set is relevant to our application as the framerate is low and the mouse is active enough as to cover the whole area of the cage. Applying the script on the 25 pictures, the following results have been obtained: 21 correct detections (84%), 2 detections with inaccurate location (8%), and 2 false negative detections (8%). Per se, the application does not generate false positive detections as it is assumed that the mouse is always in the frame. The false negative detections have been generated due to unusual mouse posture as for example a vertical position trying to climb the cage wall. In order to keep the image processing complexity low, the algorithm wouldn't eliminate these wrong answers but aim at keeping them within certain bounds. The inaccurate detections have been due to changes in lighting conditions which generated additional objects which the algorithm recognised as a mouse. They can be eliminated through careful tweaking of algorithm parameters.

A movement map is generated based on the data points as Figure 2(b) illustrates. Based on the coordinates, the path length can be computed and by adding time information we can compute velocity data and number of stops. Furthermore, each mouse will be assigned a mobility score based on position, timestamp and the number of sightings per time period. At the beginning of a time period, each mouse receives a standard score corresponding to ”normal behaviour” and the score is influenced positively towards ”hyperactive” or negatively towards ”hypoactive”.

VI. OUTLOOK

We have performed promising first steps towards a low-cost system for monitoring lab mice based on a camera sensor network. Next steps include the investigation of tracking of multiple mice in cage with substrate and grille under realistic lighting conditions. Once an algorithm has been found that provides sufficient performance, we will derive variants of those algorithms that can run directly on the sensor node. Later, we will also focus on the automatic detection of certain acitivities such as defecation. Eventually, we plan to perform a larger-scale deployment in our animal house.

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